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# SCIENCE AND REALITY

## CHAPTER I

## *GENERALITIES AND GEOMETRY*

CASTING around for a place where we may begin, let us look at some current notions of what constitutes science, so that after examining them we may give a direction to our inquiry.

If science is presented, as it often is, under the title of the search for truth—as Descartes puts it, *la méthode pour bien conduire sa raison et chercher la vérité dans les sciences*—we may object that that is not a clear-headed definition, for there are notable discoverers of the home truths that matter whom it would be absurd to class as men of science—Chaucer, for example, and Montaigne. If we start again and say that science is an attempt to "explain things," that will carry us much farther; only it raises the question of what constitutes an "explanation." To call science organized knowledge is little more than to clothe the same idea in less trivial language, and to postulate, in addition, that an explanation consists in putting given things in order. Evidently each of these views has some justice in it—searching for truth, explaining things, and organizing knowledge—and is presented in any great scientific discovery. The explanation of the motion of the heart, for example, organized in a single view a great body of facts that were either disconnected, or wrongly connected, or unknown before. It offered a mechanically comprehensible system as the explanation of the pulses and the valves in the arteries and veins, and much else. It sprang from the search for truth, and was a central vantage ground from which other discoveries could be projected, and it enabled us to do what we could not do before. It cleared the ground from error. But in the end, just how far has it carried us towards reality? That is a question of more than metaphysical interest.

Much is expected of science at the present day. No matter what miracle it gave, it would probably cause no surprise. It has become a creative element in modern life. It enables things to be done that concern us all, and that are patently impossible without it, like flying and broadcasting. And these must be considered mere foretastes of what it will accomplish, for it is only now beginning to show its power. So that I say it is a question that concerns us all, and of more than abstract importance, to ask what precisely is the nature of science and what limits must be put to our expectation from it. And that is the object of the present book.

Now we are not writing of science in the abstract, as Hegel did. The science that interests us is the science that has given us these physical wonders, and medical wonders, too, like the prevention of malaria, and will soon give us the control of other diseases.

There is no doubt that these powers derive from Nature, but the connection is obscure. The only safe way to determine what science, or any other thing, may be, is to examine its history. It is very likely that the record, when examined, will be found incomplete. It is certain that it will include repetitions and require interpretation. The necessary steps of completion, omission, and interpretation are evidently beset with great risk of personal error, by introducing an element that another person would render differently. They must be faced, however. A mere undirected enumeration of instances will not do. We must mark what is significant, otherwise we shall get lost in the detail. Yet how are we to judge? That is a crucial question and one that will always be before us. The answer is far to seek, and if we can find it, it will supply what Descartes so eagerly desired—we shall have learned how to pick out the true from among the false.

But the question I propose to treat here is not of mountainous dimensions. We are not surveying the history of science for the first time, nor attempting to compress the story of its movement into these few pages. As far as concerns the genealogy of the science that matters to us to-day, all the searching has been done. We can accept certain large, well-defined blocks of achievement, for their shape has been fixed for us by others. We can examine how they were found, and what they have furnished, what views with regard to them were formerly held and are now definitely discredited. And finally, what remains. This last is the only region in which we shall be called upon to exercise our judgment.

We may divide the sciences with which we have to deal into three distinguishable regions. They concern Thought, Observation, and Life. Naturally I do not mean that these divisions are absolute, but in such a survey as we can permit ourselves here, we can make our treatment concrete and not misleading by taking them as guides. All of them were defined, attacked, and if not conquered, were boldly and successfully invaded by Greek genius. The lines that have led to progress, and which are still pursued, were in large measure laid down then. And we may take as good illustrations of their character and differences the sciences of Geometry, Astronomy, and Medicine. We shall thus follow well-worn ground, and can pass rapidly over it, asking what lessons each has to read us. Therefore, without more ado, I shall now consider geometry, which, it will soon appear, is very far from the jejune school-exercise that the word connotes to most.

The importance of geometry in guiding thought and shaping ideas has been very great, because for upwards of two thousand years it was accepted that here at least one reached absolute truth. A body of dogma of which that was held inevitably became a norm of method, and in fact the method of geometry has been applied in consequence to the most unsuitable regions, to political theory, for example, and philosophy. But a momentous thing has happened to geometry almost in our own days. Though its arguments are still regarded as valid, they are now seen to be not inevitably so. They are conditional on the acceptance or rejection of certain suppositions. The dissolution of authority is complete. Its significance from the point of view of the present inquiry cannot be over-rated, and it will be desirable to expose the basis very clearly, especially for those who are unfamiliar with mathematics, and with the peculiar conventions, amounting to a language of their own, with which mathematicians communicate with one another.

Geometry, no doubt, had a practical origin in the measurement and surveying of land areas, but it assumed in the fourth century before our era the abstract form it has retained ever since. Every schoolboy knows that this was the work of Euclid. The following story of Euclid is found in Stobæus. As Sir Thomas Heath remarks, from whose work I take it,* one would like to believe it true. Someone who had begun to read geometry with Euclid, when he had learnt the first theorem, asked Euclid: "But what shall I get by learning these things?" Euclid called his slave and said: "Give him threepence, since he must make gain out of what he learns." Abstract as it is, there is nothing else in the history of ideas to compare with the authority exercised by Euclid's *Elements*. The trivial associations of the schoolroom make it difficult to realize that Euclid's treatise is a serious philosophical work. But it is so, and was so intended, a veritable canon of method, and was addressed not to beginners, but to grown intelligences. Though it has been re-edited numberless times, the changes that have been proposed in it are so small that Euclid's plan is still dominant, and even if they are entitled to be called improvements, they are improvements only because they rid the execution of Euclid's ideas of a certain small amount of lumber. But here we are not concerned with such details. We shall approach the book as an illustration of scientific method, and make a few remarks upon it from this point of view.

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* T. L. Heath, *Euclid's Elements*, Vol. I., p. 3. Second edition, 1926.

The work is self-contained. Every statement that is appealed to is stated in words. Whether it is practicable so to enumerate all the elements of rational construction may indeed be doubted. Euclid puts down *Common Notion No. 5. The whole is greater than its part.* If we are going as far as that, surely we require a scholium on the nature of association and what things can be put together, one to one, without creating a new *kind* of thing. But let such objections pass. The subject-matter of his discussion is contained in twenty-three Definitions, added to subsequently as required, the machinery in five Postulates and five Common Notions. Of the postulates, three are constructions and two unprovable geometrical theorems; the common notions are also unprovable theorems, but are general in character. Out of these few seeds the whole forest of geometry grows step by step. But the figure is not exact. For seeds are alive, and life cannot be counted by considering it step by step. From the point of view of the search for truth, the most immediate and striking comment to be made upon such a system is that there is no possibility of knowing more at the end of it than we did at the beginning. Whether it is a half obvious statement, such as that *In any triangle two sides taken together in any manner are greater than the remaining one,* or one that is far from obvious, such as *In right-angled triangles the square on the side subtending the right angle is equal to the squares on the sides containing the right angle;* first and last all is mere elaboration, the unfolding of the contents of the original packet. The detailed results may be of practical utility, but from our point of view the interest concentrates on two features—first, the primitive definitions, postulates and common notions, and then the logical process by which their implications are unfolded.

Considering the influence of geometry in moulding thought, it is a matter for legitimate astonishment that it can be erected on so small a base. Where do these ideas come from? What experience do they represent? Is everybody agreed about them? On closer scrutiny the constructive postulates can be reduced to this: *Let a straight graduated ruler be available.* Then there remain just four fundamental geometrical dogmas: that *things can be moved about without changing them,* and if they are, *things which coincide with one another are equal to one another;* further, *all right angles are equal,* and the famous fifth postulate, of which, perhaps, the form most obvious at first sight is that *two intersecting straight lines cannot both be parallel to the same straight line.* This is all we are given. All the rest is embroidery, fabricated from these few threads.

Now consider these few assumptions closely for a moment. As we shall frequently find occasion to remind ourselves, experience is a very complicated matter. Nature is a labyrinth, as Bacon insisted. The bases of geometry do not represent direct experience of Nature, but abstractions from it, from which all circumstances judged to be adventitious have been sublimed away. The process of sublimation consists of thinking a straight rule, when our only experience is with ones that are uneven or notched. It seems a simple, unobjectionable step. But all rulers we can try are material, and we have the strongest grounds for believing that matter is built of atoms of electricity moving in and out past one another, and in nowise corresponding to a range of points on a straight line. So it is not so unobjectionable as it seems, if we want to follow Nature. Well, but even if we cannot find in Nature a model of the straight line and other abstractions of geometry, suppose we go to Nature merely for suggestion, and let us ask if the form of these abstractions is an inevitable one. Euclid's genius laid the foundations so well that they did appear to be inevitable for upwards of two thousand years. This is a different question from the attempt to find other and better statements of his axioms, though even here there has been little success. It is a question of the content of the axioms themselves. It is now known that his system is *not* inevitable. The eighteenth century began to have glimmerings of it, and the nineteenth century, in a succession of great efforts, has created complete, coherent systems of geometry to which Euclid's fifth postulate does not apply. Therefore there is an end of Euclid's geometry, or of any other geometry, as a canon of absolute truth. What, then, is the value of Euclid's geometry, seeing it is neither real nor an inevitable abstraction? Simply this: that it is tenable. Admit his few postulates for the sake of argument, and the argument follows. You must agree with every word of it. Everyone who reads it must agree with everyone else. It is not one impressive writer who speaks of great matters, possibly in parables. It is the whole world of workers, great and small, abolishing and overstepping the time and space that separate them and uniting in a common work. This is why Euclid's geometry has been so important, though it is neither natural nor inevitable, and why it has so immensely contributed to the things we require to know. It is true that there is nothing explicit in the end which is not implicit in the beginning, but we are not always dealing with primitive ideas; we may require to know the volume of a pyramid or the surface of a sphere, and Euclid's methods will give them. A little developed, it will show that Kepler's intricate, empiric Laws of Planetary Motion imply just the law of gravitation. It is only in a very abstract sense that it is true that it tells us nothing we did not know before.

Euclid's form of argument deserves examination. The matter to be argued, for example, that *the diagonal of a square is incommensurable with the* *side,* is set out thus first, in universal terms and isolated from all other propositions. There follows a consideration of a particular square, ABCD, with a drawing of it, and a statement of the proposition as it would run for this particular square. Then by constructions which have been postulated in the beginning or have been shown to be feasible in previous propositions, and by arguments drawn from the like sources, the statement is shown to be true for the particular square referred to specifically. Occasionally, when the proposition is pretty obvious, the method strictly followed leads rather to verbiage than to increased conviction. De Morgan parodied the proof that *every circle has only one centre* somewhat as follows: "In the same village, if there is one post office and one grocer's, and if the grocer's is the post office, then the post office is at the grocer's. For if possible, let it be elsewhere, as at the draper's. Then because the draper's is the post office, but by hypothesis the draper's is not the grocer's, therefore the grocer's is not the post office; which is absurd." Gibbon may have had this sort of thing in his mind when he wrote in his *Autobiography,* "As soon as I understood the principle, I relinquished for ever the pursuit of mathematics, nor can I lament that I desisted before my mind was hardened by the habit of rigid demonstration, so destructive of the finer feeling of moral evidence, which must, however, determine the actions and opinions of our lives." Gibbon's distinction between exact demonstration and weighing evidence is precisely the distinction Pascal draws between *esprit* *de géometrie* and *esprit de finesse*. Pascal believed that the methods of geometry led to certain truth, yet he found that in matters of religion which also concerned certainties and which he estimated as much more important, it was inapplicable, and the task was one of weighing probabilities.

It is indeed a vital question whether there is a method serviceable in the search for truth that transcends Euclid's. The proposition as asserted is universal, but the demonstration offered is not in any essential respect different from the verification of a particular case. An example may be taken which is not geometrical. It is usual in books on arithmetic to prove the rule for the multiplication of fractions by counting up some particular case; thus we say $\frac{2}{3} \times \frac{4}{5} = \frac{8}{15}$, because two-thirds are the same as ten-fifteenths, and four-fifths of ten are eight. If you object that this is a particular case, it is open to you to test any other on the same model for yourself. You can take as many instances as you please and verify them, until you are satisfied. But alternatively you may agree that in the special case verified for your inspection, no use has been made of its special character, and hence its special character may be withdrawn from the conclusion. This is what Euclid does. But this method is the essence of *induction*. The step from the special case verified to the universal conclusion requires the reader to see that nothing special has been employed in the argument. As every teacher knows, this step, often taken tacitly, is a serious stumbling-block to the unmathematical type of mind.

It is exactly the step the historian makes in sifting the grain from the chaff and presenting the significant events in their just light. It is the *finesse* that must follow the *géometrie*. It is quite true that as a rule the operations of mathematics are so clear that there is no room for competent difference of opinion. But not always. Especially is this difficulty present in fundamental matters. Even Euclid was mistaken, as we now know, for systems of geometry are possible which violate his test of the intersection of straight lines. Moreover, in much less difficult and subtle cases it is easily possible to make a mistake in breaking new ground, and thus state, as a general conclusion, a result which is only true under special suppositions. A universal statement may be introduced by a *petitio principii*, a special diagram having been drawn which accidentally contains the result. And this trouble is by no means confined to the schoolroom.

Resuming, then, what we have learnt about truth and reality from geometry, which was so long regarded as its special repository, we see that there is extraordinarily little of substance, if anything at all. As facts, we have nothing but the postulates, and the ones that matter are not binding. As a method, we have to weigh each demonstration, and judge whether the universal statement is really contained in the special instance examined. We may turn from this examination to the reflection of Descartes: "After that I considered in general what is required in a proposition to be true and certain, for since I had found one that I know to be such [viz., *I think, and* *so I exist*], I thought that I ought also to know in what that certitude consists. And having remarked that there is nothing at all in this statement, *I think, and so I exist,* which assures me that I speak truth, except that I see very clearly that in order to think, one must exist, I judged that I could take it for a general rule that the things we conceive very clearly and very distinctly are all true, but only that there is a certain difficulty in remarking well which are those that we conceive distinctly" (*Discours sur la Méthode*). It seems that this intuitional test must be applied, not only to the ultimate postulates of geometry, but throughout its demonstrations. And we must remember that it has proved quite misleading as a test of the truth of the ultimate postulates.

There is, however, an important difference between the test of truth offered by Descartes, and that apparently employed in the demonstrations of geometry. In the former, any truth that is recognized is independent, but geometry is a chain, which is extended link by link. Each link is a syllogism of the standard logical pattern, consisting of a major premiss, a minor premiss, and an inference. The major premiss consists of either a postulate or a proposition which had been derived from the postulate; it is universal in its terms, otherwise it could not be appealed to. The inference is special, but is stated as general after the tacit "induction" referred to above. We make a coat of mail in this way, covering the whole body of geometry, every link of it being of universal proof. All that it says in the end was contained in its beginning; but there is no limit to the complexities that may be unfolded. If our task is to distinguish the true from the false, this chainwork is priceless in its use, for anything it cuts across must be false, or at best, must derive from different postulates.

What has been said above concerning the method of Euclid's geometry applies with little change to the other method of exact demonstration employed by mathematicians—that of algebraic symbols. Each link, as it is formed, is special, but it is tacitly passed as universal. No knowledge of truth is acquired which is not implied in the original postulates, which in this case are laws of association of the symbols. These laws are much more obscure than the postulates of geometry, so that algebra was a highly developed science before they were so much as stated and studied. We can apply no test to them except the test of Descartes—to see very clearly if they are necessary, and that, as he remarks, is the difficulty. How great is the difficulty is shown in the history both of geometry and of algebra. In the end we have learned that in the case of algebra also the system is not a necessity, because alternative systems, also valid, can be devised. The laws must be considered as arbitrary in nature, and defining the particular system of symbols that obey them.

Thus, both geometry and algebra have proved baseless as claimants to reveal inherent truth, by the convincing method of producing other claimants with titles equally indefeasible. Can we solve the difficulty at all? That is the problem.

## CHAPTER II

## *ASTRONOMY AND THE OBSERVATIONAL SCIENCES*

We have been able, in the last chapter, to make survey of geometry. From the point of view of a searcher for truth, it has proved barren and artificial to a surprising degree. This is not a matter of the smallness of the contents of the postulates in comparison with the elaboration of the science. On the contrary so long as its postulates were regarded as inevitably true, they might be considered as embodying in a wonderfully compact and reduced form all that we know of the space in which we exist. But since they are not inevitable, they may be true or false—which means they are probably false—and space may be what they imply or it may not, and we are at liberty to use our judgment in the matter—in other words, we *know* nothing. Every link of the demonstrations of geometry equally demands the use of our judgment in order to see whether some special property of the case examined has been imported into the conclusion that is drawn. Evidently nothing more can be made of geometry. We must abandon it as a means of finding the truth. Let us, then, turn to a different system of investigation.

Geometry was originally, one supposes, a practical affair, but at a very early date its appeal to things outside was replaced by abstractions, the connection of which with external Nature was so fine and so remote that the mind itself monopolized the whole court and became judge, jury, and litigants in one. No appeal was possible because there was no other court to take it to. The system has been made perfect, only unfortunately it cannot tell us what is true. Admitting that nothing more can be done that way, let us turn to a science that requires continual reference to external Nature. Now astronomy is a science in which the mind must certainly travel beyond its own bounds. It is as old as geometry, if not older, and has been worked at by minds of far more varied type. The certainty of its conclusions, and even of its prophecies, has long been a proverb. And there is no competent difference of opinion in the main lines of true and false in regard to it, and the significant steps of its development. Let us, then, make a survey of what it has to say, in particular as to what claims its doctrines have to be true in other than a transient sense, and what methods have been followed in acquiring them.

In geometry we have a science which for the greater perfection of its methods, and to secure a purity for it which practical applications are obliged to forgo, has been shielded from a very early date, until it has become wholly an internal affair of the mind, a drama which the mind "does for itself contrive, enact, behold." In contrast with this, if there is any meaning at all in the terms *internal* and *external*, the subject-matter of astronomy is external. Except the earth, which at first hardly appeared to belong to the problem, the bodies concerned are inaccessible, and except for the sun's heat, were known only to the sense of sight. The problem was to collect and to rationalize the sensations. To realize what that means we must put ourselves back for a moment alongside those who had not yet succeeded in doing it.

Astronomy had not always the clear framework of geometrical relations and motions that the name now calls up. We need not speculate on unknown and unintelligible forces that reach right up into the foreground of the picture presented to primitive man. But all experience is presented in a tangled mass and requires unravelling. Where the unravelling seems easy and proceeds rapidly, it means merely that we have accepted an agreed, a conventional procedure, which is not therefore necessarily a true one, and may indeed exclude possible and most vital alternatives. But let us not go back so far. Take a stage when the geometrical character of the astronomical problem had declared itself with some distinctness. Among the commonest monuments of prehistory, dating, one supposes, from a definite epoch in a people's development, are those that mark the point where the sun rose at midsummer. As soon as the scientific spirit of observation awaked, with its desire to explain things, the changing point where the sun rose from below the horizon must have engaged attention. In our latitudes it swings from south-east in midwinter to north-east in midsummer, and back again, in endless alternation, which is associated with the lengthening or the shortening day, and with the spring of the year on the one hand, and the fall of the year on the other, and their innumerable associations with animal and plant life. Cromlechs and monoliths are a legacy of our ancestors to prove their recognition of the fact and the importance they attached to it. Now, when an association is evident, it is natural to try and make it simple. But by this time we are used to finding a deep chasm separating us from a visible goal, with the necessity to cut a great many steps, down and up, before we can reach it. So perhaps it surprises us less than it should that the obvious, natural facts that struck our ancestors require from our point of view, for their geometrical analysis: (1) a round Earth, (2) revolving around the Sun, and (3) rotating on an axis, (4) oblique to its path of revolution. Nowadays, when geometry speaks, it is listened to, or, at any rate, it is not contradicted. But if we want to see the effect of such an explanation before spontaneous criticism had been cowed, and note the reaction of the geometrical explanations of astronomy upon a powerful and sensitive but unmathematical mind, we may turn to the book *De Rerum Natura* of the Latin poet Lucretius. Two hundred and fifty years before the time of Lucretius all the direct phenomena of astronomy were understood very much as we understand them to-day. Even the annual revolution of the earth about the sun had been taught, by Aristarchus, in a treatise which Lucretius may have read, though it is now lost. He certainly read the teachings of geometers current in his day, and he summarized them in his poem, for the most part, with the precision and economy which are only in reach of a man who has a genius for the value of words. But he attached no force to the explanation he recorded. They were not to him the links of any evitable chain that could not be broken. They were just guesses, and their subtleties therefore were only perverse contortions. He preferred to imagine, for example, that the stars were fiery creatures that wandered round and round through the æther, searching for their food.

> ipsi serpere possunt,
> quo quoiusque cibus vocat atque invitat eunteis,
> flammea per cœlum pascenteis corpora passim.*

Again in explaining the moon's phases he gives first a clear summary of the correct explanation, which he quite understood and even approved, for he adds with regard to it

> propterea fit, uti videantur dicere verum,†

but thereupon follow two other explanations that are not rejected, and, finally, apparently the one he prefers to all:

> denique, cur nequeat semper nova luna creari
> ordine formarum certo, certisque figuris,

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* Lib. V., v. 524. "They may creep around themselves, feeding their fiery bodies in various parts of the sky, each going where his food invites him."

† Lib. V., vv. 713 *et seqq.* "Thus it appears that they seem to speak the truth."

inque dies privos aborisci quæque creata,
atque alia illius reparari in parte, locoque;
difficile est ratione docere, et vincere verbis,
ordine quom videas tam certo multa creari.*

Evidently to Lucretius, with the fruits of Greek theory before him, it appeared the natural course to explain things in terms of life, and not of geometry. These are his own views, where he is free from his set task of grinding out the atomic theory. We do not do that now. The idea of the stars prowling around night after night, like hungry dragons searching for their food in the fiery æther, strikes us as extraordinarily quaint; and the creation of a fresh moon every month, to grow and then die away, appears in our eyes the negation of an explanation.

We are very sure that we are right nowadays, and that Lucretius was wrong, but as we are here engaged in reviewing scientific method, it is worth while to give our reasons.

The reason why we object to the idea of the stars wandering at their own will wherever their food invites them, is that that hypothesis opens a worse rent in knowledge than the one it closes. The food of the stars and their volition have been introduced

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* "But why a new moon should not be created each time, with regular order of shapes and phases, and each one created die off in due course, and another appear in its place and function, is a difficult matter to settle by reason and prove in words, when you see so many things created in regular order."

*ad hoc*. Attractive as the picture may be, in a poetic sense, it is far from an attractive task for the philosopher to define such things. But if we keep to the jejune hypotheses of geometry we are at least dealing with what we can define. It had already been done by Euclid, for all time, three hundred years before Lucretius wrote. Given a state of culture that permits a free choice, and given a certain type of mind, we can understand how the hypothesis of the earth as a huge globe rotating upon its axis, when common sense says it is flat and fixed, may seem a more far-fetched supposition than that of creatures prowling for their food, yet it does not commit us to anything we cannot scrutinize. And in this respect we may be completely satisfied. We are in a region that is so far different from that of geometry that the things we require to explain demand a continual appeal to facts outside ourselves, as much, that is to say, as any fact is outside ourselves. As far as this limitation allows us to determine them, the facts of the diurnal motions of the stars agree perfectly with the hypothesis that the case is covered by geometry. There is nothing more to say. From the point of view of an explainer, the almost complete emptiness of geometry is its chief beauty. His explanations are a penalty to him. He is happiest when he is discharged from his duty of explaining and can say "There is nothing to explain."

How large a part of astronomy a geometrical description suffices for is too well known to need restatement. For all such phenomena we may say that no explanation is needed, they are simply *there,* nothing will simplify them or put them in better order, short of a rehandling of the postulates of geometry itself. They are primitive facts—mere truths—which have been picked out from among fallacies. If geometry is valid, the explanation of them is valid, and conversely. The ambiguity or limited relativity which geometry allows is even an advantage, for it permits suspense of judgment in such questions as the rotation of the earth. Whether the stars are fixed and the earth rotates, or the earth is fixed and the stars rotate, is not an affair of geometry. It is a question of judgment. Thus the history of astronomy for many centuries might be described as a search among the phenomena for any residue that could be shown to require explanation when the merely geometrical descriptions were struck off. This first declared itself in a way that all could see when Copernicus had accomplished his great inversion of ideas. Discoveries are seldom made once and for all, nor was this one. But we are not concerned with the details of its history. What matters is that, once the sun was made the centre of the system of planets, and they were seen to move in ordered manner around it, it became manifest that bodies influenced one another's motions, and that there were regularities in the scheme for which mere geometrical description, or, as we can now add, the concepts of the old space alone, could offer no explanation. In other words, after an extremely patient and thorough sifting of the phenomena, conducted competently for some nineteen centuries, a residue was at last found which the time-honoured solvent of geometry could do nothing with.

The bodies influenced one another's motion. The residue requiring explanation was motion. This may seem a strange statement, seeing how much of astronomy has always been concerned with the motions of the heavenly bodies. But this motion was always figured as circular motion which repeats itself perpetually, and so does not force us to discard the conception of a fixed geometrical figure. Even in the case of the motion of the moon, which was known to differ widely from a circle, the device was employed of patching one circle on top of another, until a result near enough to be called satisfactory was attained. We do all we can to escape the idea of change. The conception of an orbit, which is a figment, replaces the fact of a changing sequence of configurations by a fixed geometrical figure from which all reference to time has been eliminated. The old geometry was a timeless conception. And its method of argument was held to be the only completely demonstrative one. As a demonstration covering the new phenomena of motion was necessary, appeal had therefore to be made to the geometry of Euclid and Apollonius, as Newton conceived the task. But this required the paradoxical feat of introducing change into a changeless system.

Motion is a primitive fact; everything is in motion. None the less, the motion of any defined thing has figured as a paradox from the earliest times. If the dilemma threatens to pin us down—"a thing moves either where it is or where it is not," both of which must be rejected—the escape is, presumably, that the conception of a " thing " apart from its motion is untenable. Subsequently we shall see ample reason to return and examine this point more closely, but in the meantime let us suppose Newton's miracle done, or the impossible so adroitly covered up that the sleight of hand is invisible, so that we have called into being a calculus of changing quantity, secure in its method of demonstration, link by link unassailably, like the old geometry which dealt with one and the same given figure.

The calculation of change is a necessity of exact thought in dealing with the things of Nature, and, needless to say, was not first made by Newton nor in the seventeenth century. " Quadratures " and " Cubatures " of curved figures are among the details of our legacy from Greek genius. But Newton reinvented all that he used, and gave it foundations so profound that we must approach the question with a wholly different order of ideas if we are to displace the foundations successfully. This, however, was only one part of the machinery he required. If bodies influence one another's motion, as it was evident they do, we must say how, or at any rate in what measure, they do it. He treated this problem also by the methods that had become accredited through use in geometry; he laid down first a completely general dynamics, described in postulates or " Laws of Motion," from which, by application to the special case of Nature, it could be ascertained what in particular Nature had to say; or, in other words, in which respect Nature was less general than the metaphysical "laws of motion," which had been postulated as laws of matter just as the postulates of the old geometry were taken as laws of space.

When this machinery was applied to the facts which I have described as astronomy's non-geometrical residue from observation, two results emerged: first, that bodies were signalized by a certain permanent coefficient, the so-called "mass" or quantity of "matter," which had nothing to do with their size, shape, or motion, and in virtue of which they reacted on one another; and second, that in those widely separated tracts with which astronomy deals, the same masses attracted one another in a way that changed with the distance between them, being quadrupled when the distance was halved, and so on. Strictly the results were proved by Newton only under astronomical circumstances—that is to say, when the isolation is immense, and the bodies may be treated as though condensed to points. But it was his practice to prove rules by particular cases, and then "render them general by induction." Induction, as we have seen, means the exercise of judgment. Newton judged that these laws of mass and attraction were indeed coextensive with Nature, and he put the supposition to various tests, the most famous being a verification that the force which holds the moon in her orbit round the earth is no other than that which makes an apple fall or a pendulum swing at the earth's surface. Therefore he enunciated his laws as universal, and for upwards of two hundred years no flaw could be found in them.

Considering that the source of these laws was the study of motion, perhaps the most remarkable feature in them is that motion does not figure either in the property of mass or the law of gravitation. Indeed in the statement of the mass-coefficient of a body neither space nor time figures, while the law of gravitation has a geometrical shape from which all symmetry is lost if reference is made to time. Either the self-existence of geometrical figures is confirmed by these laws, or else it is an illusion which has been forced upon the facts of Nature by an obsession of the geometer.

What more there is to say upon this matter will come later. But let us now turn to the most recent chapter of deductive astronomy, which is a reconsideration of the laws of mass and of gravitation.

It is clear from the course of the discussion in the present and the previous chapter that Euclid's geometrical postulates, and Newton's laws of motion have no claim to authority if they do not fit the facts. " Self-evidence " is no test. If it is not tautology it is affirmation of something—which might be otherwise. Now the genesis of Newton's laws leaves them exposed to two criticisms that have grown in force in recent years to a point he could not possibly foresee. He derived them from astronomy, in which the masses are reduced, in effect, to concentration at points. True, the finite dimensions were afterwards considered. But we now know that even if we cut gross matter up into its atoms, we have not said the last word. The atoms of matter are built up of electrons and protons of electricity, in defined patterns that are quite well known. Now, electrons do not possess an amorphous mass-coefficient, such as the mass law would require. Their inertia depends upon their speed and is different in different directions. The mass-property of Newton must be regarded as a gross and statistical treatment of the facts, and not an ultimate one. We must be prepared, for example, to find great condensations of matter, such as the sun, affecting *per se* the transmission of light in its neighbourhood, which is an electro-magnetic phenomenon, or again qualifying in a peculiar way the light that it emits. We must expect to find it attracting a rapidly moving body, such as Mercury, by a law modified from that of the inverse square of the distance. All these have been verified, the first two being verified as predictions of Einstein's "restricted relativity," which is consistent with Euclid's geometry. But, as everyone knows, Einstein has gone much farther than this. Euclid's geometry postulates a certain mode of space measurement. Starting from the postulate that all specific modes of measurement are indifferent and arbitrary, including the distinction of time and space, and that accordingly no one of them must be implied in a statement of a law of nature, he has succeeded in obtaining a form of statement for the fact of gravitation, in terms that agree with such a postulate, if we allow Euclid's "flat" space to go. And what right have we to retain it?

From every point of view this work is a profoundly interesting development. To us at the moment the most important question is, "What prejudices has it rid us of?" This is easily answered. Euclid's geometry of flat space ignored time and did not prove space to be flat. Nor does matter prove space to be flat, nor does it furnish a reason for distinguishing time from space. But there remains the fact of gravitation, under whatever name or guise it appears, which no possible remodelling of the space-time concepts can efface.

If anyone is dubious of the scope and limits of the use of deduction, he should consider Einstein's Relativity. It represents the summit of what deduction can accomplish. It is not a question of measuring up his feat as greater or less than feats accomplished by Archimedes or Newton, nor even against those of Lagrange or Gauss. In none of their days was the ground sufficiently broken in the preparatory ideas, nor the machinery of analysis developed to its full power. Without any empty laudation we can say that he has given a concrete example of the limit of what analysis and deduction can reach. It has cleared our thoughts of things that were unnecessary, mere scaffolding that can be stripped from the completed building. But that is all. The new statement he has given of gravitation is no more than a proof that the distinction of time and space and all special methods of measurement were mere prejudices, and like Euclid's parallels postulate, unjustified by anything we *know*. The new facts that his theory has revealed follow from the electro-magnetic constitution of matter, and would have been so explained when they were observed—beyond measure less strikingly—but that is not material to us here.

Having thus plumbed deduction to the bottom, let us now turn another way. When Galileo turned his telescope on the moon he saw that it had mountains; when he turned it on Jupiter he saw that Jupiter had moons—*incredibili jocunditate animi,* as he remarks. Instantly he read the right conclusion, that the heavenly bodies were bodies of the same kind as the earth. And going further, "Is not the sun a great earth vehemently hot?" asked Newton. This "induction" remained an induction until the spectroscope demonstrated that the sun, and afterwards that the stars too, were composed of the same chemical elements that were known upon the earth. Two sciences then joined hands. Physics, the science of the nature of things, had existed with respect to what we can handle, from the earliest date, but had consisted of disconnected though very numerous phenomena. Astronomy had made advances in the knowledge of truth, unexampled in any other science; but appeared completely detached from everything we can feel, handle, or experiment upon. But from this epoch onwards astronomy, in the eyes of the physicist, became an extension of his laboratory to deal with masses, isolations, periods of time, speeds, temperatures, and pressures, that were utterly impossible for him before. He could not control the experiences, but on the other hand that was an advantage, for experiments were going on that he would never think of, and in such endless numbers that he had only to search diligently, in order to find ones that applied. Astronomy was no less a gainer. By contact with the earth its problems had suddenly crystallized. In a certain sense astronomy had become geocentric again, for the things we find around us were found to be also universal.

A change came from this union of physics and astronomy, which concerns us from the point of view of method. Guesses at truth, in other words, " inductions " of more or less validity, had always been made. You cannot prevent people from guessing. Aristarchus guessed that the earth went round the sun. Giordano Bruno, who was burned for many heresies, guessed that the sun was a star. Galileo guessed that the moon was a rocky body like the earth. Newton guessed the distance of the sun and the density of the earth. F. G. W. Struve guessed very correctly the scale of stellar distances. When people of that quality make guesses a great many of them are right. One may say that there are few things which are not seen and known first and proved afterwards. " Deduction " may not have lost its authority, but the bearing of inquiry was changed when it became a question of search among the examples of astronomy for ones that supported this or that guess and were significant of this or that view—a view or theory that had been already formed tentatively and seemed to its author probably true, but lacked only admitted facts in support, sufficient to demonstrate it. This was a less lofty method than deduction. The seat of the inquiry had been let down because " a lower seat was easier." That was nothing new. It was a return to the beginning with its search for *any* regularities. In the biological sciences, which are coeval with astronomy, the high places of deduction and demonstration had never been accessible, let alone practicable as a method to use for advance. Where they had progressed beyond enumerations, regularities were noted here and there, and tentative deductions formed a rudimentary linkage about them. In some cases these views were extended to form an unlimited conspectus, as in the theory of evolution, but even there nothing was final; all was provisional and liable to be swept away if a more significant grouping of the elements could be found. The method is mere trial, but it leads to a control of Nature, which I take as sufficient evidence of an acquisition of truth. Yet as a method it has no authority which a philosopher would regard for a moment, until we reach the ultimate test of Descartes—that someone has seen very clearly that the thing was true.

The change in method in astronomy, by which it follows the same lines as physics, and also the same as the biological sciences, are forced upon us by a closer knowledge of the stellar field. Where the stars are numbered by millions, one has only two resources for investigating signs of system. One is to choose one's examples. Examples of what? That must be settled before one begins to choose, and amounts to an exercise of judgment of what will stand examination. The other is, to group large numbers together and trust to the statistical elimination of variations. Again one asks, variations from what? And the only answer is, that the line of grouping must be determined before we begin to group. If one has no line it is certain one will get nowhere. That was the cardinal want of Bacon's method. And the line of truth can only be determined by an exercise of judgment.

This method of procedure is an untidy method, very different from the quarter-deck exactness of Euclid. Hypotheses that are dead, or semi-animate, or in a state of suspended animation, are scattered around us in every direction. It is impossible to say when one supposed dead will rise up again and take its place among the living, nor when one apparently full of breath will suddenly give up the ghost. The excuse is, that untidy as it may be, it serves. Those who practise it may claim that proof, to the exclusion of alternatives, is a final stage, a point that is never reached until the truth, for all practical purposes, is already known. Proof becomes a luxury, an ornament, and therefore a costly burden upon progress, rather than the necessary preparation for it. Those who are more concerned with facts than with methods may readily think they can dispense with it.

More than that, they may take up a more aggressive attitude and say, "Is not your demonstration really a sham? All you can do is to verify a particular assertion, as Euclid does, before he winds up with his flourish, 'Therefore, etc., Q.E.D.' To see that you have really proved something general is as much an exercise of judgment as are the reconstructions of prehistory. And, finally, you can usually fit the method, with all its frills, only to cases that are so simple that they are devoid of interest."

I have connected my remarks with the history of astronomy for several reasons. Astronomy is very ancient. It is much more complete than most sciences, and it has been very successful in its search for knowledge, although one would say that the material it must work upon was extraordinarily inaccessible. Its subject-matter is definitely external to the observer. Its results have repeatedly transcended the ideas of it formed in advance. It has used both the method of deduction and that of the verified guess. It has completely inverted and turned inside out its description of things more than once.

Astronomy has furnished the occasion for the invention or application of the most fruitful methods of research yet found—deductive, statistical, or observational. Thus there is very little to be said elsewhere that cannot be exampled in astronomy. But perhaps my chief reason for giving it so predominant a place is that I wish to discuss actual science, and examine the real methods; and astronomy is one in which I can claim some first-hand knowledge, and can speak of the real bearing of the methods upon its advances. But I would add a few complementary remarks, from the history of the other sciences, which I trust will not be found to contain any serious misapprehensions.

Among the physical sciences, physics and meteorology are both nearly coeval with astronomy. The reason why they have been so much slower in development is that the matter they deal with is too near us—all the points of interest present themselves at once, mingled and undistinguishable. While the sun, the moon, planets, and stars, because of their inaccessibility, separated themselves clearly, and so to say, made their own abstractions, in physics many centuries passed before the nature of the air we live in was even approximately understood. There is perhaps an equal interconnection of things in astronomy, but it presents itself gradually. Physics did not immediately suggest its own division into elements. Now that we understand what elements we are dealing with, physics can proceed, and is proceeding very rapidly by experiment. Each experiment may be considered as the verification of a proposition. The experiment may or may not lead to a general inference—that depends upon the experimenter's judgment. Often he considers that he knows more than he can prove, and often he has been right. It is the effort of the experimenter to seize some general point of view—if possible a universal one—such as the one which gave the Michelson-Morley experiment on the transmission of light, so that an impermeable chain-mail of deduction may be formed around it, and extend to great distances. The clearest examples of the method are the earliest, Gilbert's *De Magnete* (1600) and Newton's *Opticks* (1704). But it is seldom now the aim of an experimenter to make his conclusion universal, like a proposition of Euclid. It is recognized too clearly that that is generally unattainable. In place of making the postulates remote, abstract, and very difficult to seize, they are usually frank hypotheses, close at hand, and the clearer the better. "It is far more important that a theory should be simple than that it should be true," may be taken as a characteristic declaration.

This procedure may lack the old-fashioned pose of dignity, and may seem hardly worth philosophizing about, but whatever its character, it appears to be close to Nature, for its progeny increase and multiply and inherit the earth and subdue it. Whether one would predict it for them or not, they do, in fact, enormously and increasingly yield into our hands control of Nature's processes.

There is a region of physics beyond laboratory experiment where it touches astronomy on the one side and meteorology on the other. Here it is as though some power outside were making experiments, continually and in vast numbers but without design. In meteorology, for example, all the factors are physical, but they are usually all present together, in a way that does not permit one to be subordinated to another as of minor importance. In spite of this, by careful and patient watching of what goes on, the problems are now beginning to take a manageable shape. As in the stellar field, statistics, and the selection of examples, and rudimentary deductions extending their scope, have succeeded. Indeed, they must succeed, for whether they produce much or little, fast or slowly, they produce something, and everything produced is added to the heap.

The science of chemistry is the home of experiment, but there is nothing that need be said about it which has not already been said of physics. I will turn very briefly to medicine and the biological sciences.

When a physicist makes an experiment to determine the gradient of electric potential in ascent from the earth, if a shower of rain supervenes, he will get a wholly anomalous result. Nowadays he does not attribute this to witchcraft or to supernatural powers. On the contrary, he is confident that nothing beyond physical forces are in play, which he can reckon with, if only he takes more pains. But when an investigator deals with life, that is far from certain. In fact, there is no basis for the assertion. It is made only because it would be more convenient for the purpose of investigators if it were true. The nerve structure, for example, may be followed to finer and finer tendrils of differentiation, up to the limit of what the microscope will reveal. Its importance, however, would be nothing if it were not related to psychosis; but where does psychosis come in? The two are different in kind, and if we could follow the physical system of nerves down to the last atom and electron, we should not expect to find the secret of psychosis lurking in some pocket. Yet psychosis, consciousness, and the *I am* are so familiar to us that savages attribute them promiscuously to all things, and Lucretius, when he found physics difficult to believe, turned to life for an explanation, and Descartes took it as the one certain starting point for his meditations. Hence there enters an enormous difference when we pass over to the sciences that deal with life.

Contra vim mortis
Non est medicamen in hortis.

A man will die in the end whatever we do. For all that there is a science of medicine. But it is evident it must be a restricted one. In its nature it must be totally different to the physical sciences, for no matter how far we go, we do not expect to state in physical terms its first characteristic, the nature of life itself. Now the actual methods it has practised are well known. As the chemist or physicist brings some force or reagent into play, and studies its effect at the other end of a sequence of connections, the details of which may be highly artificial and which, once established, he dismisses from his mind, so a drug or stimulant may be administered and its effect may be studied in heart-beats, or in change of chemical balance, or what not, in a living body. The stimulus is physical and the observation is physical; the living body that connects them is ignored, if possible. The defence of this method is first, that it is feasible, and second, that it gathers knowledge. Later on we shall have more to say of the nature of the knowledge acquired. But it is obvious that the hypothesis that between the physical beginning and the physical end the living medium may be ignored, though bolder than the tentative hypotheses of physics, is on somewhat the same footing with them. If it works, it gives us something; if not, we may discard it and try again. Therefore, we have in the sciences that concern life also a cumulative method which adds piece to piece until in the end a vast body of knowledge is accumulated, which we cannot deny to be real, however partial or external or insufficient we may find it.

The limitations of the physical view of medicine are well known, and a certain science has always been practised that attempted direct influence, and of late it has been reduced to some system under the name of psycho-therapy. We need not here do more than direct attention to its existence. It recognizes the deficiency of the physical view, but at the same time it aims at using some part of the systematic method that physics has found successful.

# CHAPTER III

## *THE BUTS OF THE PHILOSOPHER*

We have seen something of the history of science as it actually is, in the last two chapters, with an eye specially directed on its methods. For the purpose of this volume is to determine what, after all, science amounts to. It will be disclosed in the present chapter that the philosophers of the schools have from the earliest date regarded its claims to reveal reality, which is their special charge, as dubious or worse, and that they have found no reason to change that attitude with the lapse of time. But before considering their strictures, it may be convenient to call on science to report its progress and declare what it has accomplished, so that we may have before us in specimen, or in summary, or in outline the things presented for judgment.

Progress, in amenity or safety, by means of adapting our conduct to circumstances, is by no means confined to man. With other creatures it figures as mimicry, most commonly. Many of the cases may be supposed to be forced upon the creature by some signal advantage, but we can mention also unessential instances. We have the case of the starling improving his song by copying more gifted birds. There are cases, too, that show "experiment" and "progress." The gull may be seen on grass lawns pattering rapidly with his feet and seizing the worms that come out in consequence, a habit far from his mode of living and so trifling in food-value that it must be a mere pastime which he has learned. With us, knowledge that has been acquired, and changes of habit in consequence of it, mask completely what Nature provided. Collecting casually a list of things, without the least attempt to be exhaustive, we work back from flight and broadcasting to X-rays, modern surgery, synthetic chemistry, plant genetics, motor-cars, electric light, railway trains, steam boats, power tools, telegraphs, newspapers, telescopes, printing, soap, glass, gunpowder, steel, iron, bronze, writing, domesticated animals, weapons, tools, clothing, cooking, fire, speech. As far as we know their history, all these have been found by the methods considered in the last chapter—trial and adoption. All of them hang together. Once started, they form an almost inevitable group, which might have been varied perhaps in sequence, but not very much in that. It is not a question whether the world would be a better place without this or that member of the list—explosives, for example, or poisons. That seems to be rather a matter of the use they are put to than the nature of the things themselves. Nor whether man has degenerated in the security they have given him and lost his power of muscle and sense by softness. Nor to what degree he has overtaken by multiplication of his numbers the advantages given by an increased control of Nature. Nor whether he has counterpoised his advantages by the simultaneous invention of ingenious vices and artificial necessities. Taking one glance over civilization in this hurried sweep, we see that good or bad, sooner or later, it was all bound to come, like the river approaching Niagara, gently at first, with imperceptible motion, then steadily, visibly, and irresistibly moving, now verging to a torrent, and thereafter—thereafter the figure of speech breaks in pieces, being unequal to prophecy. But the movement is so great and irresistible that it is difficult even to take seriously an inquiry into the nature of this knowledge. If this is not truth, where is truth and what is truth? It must consist of something entirely impalpable.

But the philosopher is quite used to being in a minority and shouted down. It does not shake his mind in the least. Let us, then, give an open hearing to what he has to say. Characteristically he begins with the Greeks.

I take the following from the *Encyclopædia Britannica:*

"Pyrrho of Elis (*c.* 360-270 B.C.), a Greek sceptic philosopher and founder of the school known as Pyrrhonism . . . was diverted to philosophy by the works of Democritus . . . he went to the East in the train of Alexander, and studied in India under the Gymnosophists and under the Magi in Persia. . . . Returning to Elis, he lived in poor circumstances, but highly honoured. . . . The main principle of his thought is expressed in the word *acatalepsia,* which implies the impossibility of knowing things in their own nature. Against every statement the contradictory may be advanced with equal reason. Secondly, it is necessary, in view of this fact, to preserve an attitude of intellectual suspense. . . . Thirdly, these results are applied to life in general. Pyrrho concludes that since nothing can be known, the only proper attitude is imperturbability. The impossibility of knowledge, even in regard to our own ignorance or doubt, should induce the wise man to withdraw into himself, avoiding the stress and emotion which belong to vain imaginings."

There are a good many questions we would like to ask, but we must invent the answers to them. The tradition of Timon the Sillographer is a little dim in places. Nevertheless, it comes through that Pyrrho was some sceptic.

For a broad view, skip to *As You Like It.*

" Hast any philosophy in thee, shepherd?"

" No more but that I know the more one sickens the worse at ease he is; and that he that wants money, means, and content is without three good friends; that the property of rain is to wet and fire to burn; that good pasture makes fat sheep, and that a great cause of the night is lack of the sun; that he that hath learned no wit by nature nor art may complain of good breeding or comes of a very dull kindred.

" Such a one is a natural philosopher."

Yet hear David Hume:

" If we believe that fire warms, or water refreshes, 'tis only because it costs us too much pains to think otherwise " (*Treatise on Human Nature,* Bk. I., iv. 7).

The first impression on reading these words is that we make a sufficient reply if we say that David Hume was talking nonsense. But that is not so. The fire is *given*, and the warmth is *given*, in this case through different senses, and we supply the causal connection. Why we do that, or whether we should, is just the question. There is something missing. If we care for verbal polemics, we can turn defeat into triumph by saying that the gap is a proof of some transcendant medium in which the All subsists, and developing with appropriate rhetoric. None the less, there is a rent in the garment, though for convenience or to make a brave show we habitually cover it up and forget it. But Hume was of the type that put his fingers through the rent and played with it and brought it to the front until, he tells us, it became an obsession; he could think of nothing else, and had to bring himself back forcibly to the habits of Touchstone's "natural" philosopher, in order to live an everyday life.

When there is a gap in an argument, it can only be ignored if all parties find it convenient to do so. Otherwise it is well known; it is only a question of the necessary skill and the gap can be made to stand out here or there, anywhere you please, in each and every part of the system. Philosophy, where it is not mere verbiage, is largely a study of these gaps. Therefore, though no new themes are added, philosophy permits, and requires, continual restatement. Bidding good-bye, then, to Pyrrho and David Hume, to whom science, as we know it, was non-existent or a remote vision, let us take up the same difficulty as it has been presented by Lord Balfour for men of to-day. His writings on this subject are well known. They begin with the *Defence of Philosophic Doubt* (1879)—that is to say, a philosopher's doubt in the necessary validity of the conclusions of science, which at that date were given with something of the air of dogma. Recent as the date is, the air has long since blown away. But the problem remains, and Lord Balfour has restated it in an address to the British Academy in 1925,* from which I quote some passages.

". . . I find within the general body of my beliefs about the concrete world a central group which influences all my practice and colours all my theories. Let me mention some of its most important members, premising that the first of them occupies *for me* a unique position. I believe (1) that I am a person, (2) distinguishing myself from all other persons, though (3) never doubting that other persons exist, or that (4) communication with them is a necessary element in normal life. I believe (5) that these other persons resemble me in possessing and exercising capacities for feeling, perceiving, willing, remembering, reasoning, and so forth; that (6) we all inhabit the same physical universe, (7) of which we can move small portions at our individual will, and (8) that in similar situations we usually perceive the same sort of things in much the same sort of way. I believe, further, that the physical universe is (9) extended, (10) enduring, (11) changing, though through all its changes (12) it exhibits regularity, and (13) goes its own way, scarcely modified by the beings who live in it, observe it, and depend on it.

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* *Familiar Belief and Transcendant Reason. Proc. Brit. Acad.*, 1925.

"For me, and I suppose also for you, this string of loosely expressed platitudes . . . are not only fundamental, but also inevitable, and by 'inevitable' I mean that, whatever be their position *de jure* in the creeds of men, their position *de facto* is impregnable. This, at least, is true so far as I am concerned. I cannot escape from them even if I would. Theorize about them as I may, my faith remains unshaken.

"Is this cautious phrasing (it may be asked) intended to suggest that the beliefs I have just declared to be fundamental and inevitable are ill-fitted to bear the strain of critical examination? That is in fact my opinion. Elsewhere I have given my reasons for it at length, and in so far as they are accepted, it seems to follow that these central principles, though they dominate our lives, occupy a position which, from a philosophical point of view, is eminently unsatisfactory. For they cannot be proved; they cannot be ignored; they cannot be rejected; nor (with the exception of the first) can they be regarded as self-evident."

A philosopher cannot complain if his warnings and strictures are taken philosophically. The world considers him an unsafe guide. Even he himself would admit that many other philosophers have been wrong. When Pyrrho preached doubt and indifference, the world did not attend to him. It was not in a static state, but it was very unclear in what direction it was moving. It was not a surprising choice that he should turn his back upon its rewards, nor would he expect nor care that the world should follow him. When Hume lived, the world had moved, as we now see, a long way along a definite path. But that the motion was along a determinate groove was not striking to his contemporaries. It seemed only to have changed one form of civilization for another. Amenities of life, like coffee and tobacco, brought from remote parts of the earth, did not carry any particular significance, nor forecast the artificial state of to-day, when three-fourths of our population depend upon imported food. Life still seemed pretty closely shaped by the whim of nature and of fortune. If in consequence of the great severance Hume made between "Cause" and "Effect," Priestley and Lavoisier and Cavendish had ceased from their labours and had had no successors, Hume could not have foretold the illimitable consequences. But nowadays it is a different story, and Lord Balfour has put the case to us differently. He has stated in general terms a "string of loosely expressed platitudes" that we can neither prove nor reject. As to that, a proposition we have heard so often that it has ceased to impress us, may or may not be a platitude, and if they are "loosely expressed," presumably it is by design. Whatever else they may be, we can recognize in them the whole and sole philosophical armoury of the average scientific man. All the actions of the scientific man, and, therefore, his doctrines and discoveries, depend upon them. He cannot be indifferent to their bearing. Let him, on the one side, look at the hasty enumeration of things given a page or two back, which man has already found, all by such methods as the man of science is handling to-day, transforming the world in which he lives, and certainly bound to transform and dominate it in a far higher degree in the future, and then let him ask what bearing Lord Balfour's remarks have upon it. So long as man's activities did not seem to be capable of modifying the world in any determinate way, Hume's dilemma was merely a curiosity of the intellect. It is in quite a different position when the fruits of these efforts have already displaced Nature to such a degree that I suppose nine-tenths of us would perish if we had to find our own food and otherwise face Nature's conditions unaided.

One allows, of course, that a man may be very effective in scientific discovery, and yet take no interest in these philosophical questions. Still more commonly does it happen that a man is much more highly qualified for success in one of these branches of ideas than in the other. Newton's and Faraday's opinions in theology are a matter of biographical curiosity only. If anyone feels that it does not matter that the propositions of science are in a profoundly unsatisfactory position philosophically, because it has always been so, and science has grown and grown nevertheless, and will continue to grow—*non ragionam di lor*, my argument is not for such. This inquiry is written for those who take a logical lacuna very seriously. If there is a defect, a want of symmetry, or a presupposition always present in one's method of work, it is to be presumed that the outcome will be modified in a determinate way. In what way? If the outcome is one which is fated to dominate life in the world, as most assuredly this one is, the way in which it is warped by an error or a gratuitous postulate cannot be too earnestly sought or too clearly determined.

## CHAPTER IV

## *THE LIMITS WE MUST ACCEPT*

*Bien conduire sa raison et chercher la verité dans les sciences*—Descartes' goal and method, too, have faded like a ring of smoke. What hope is there of steering reason aright, so as to arrive at truth, when reason appears to be no more than a link between phenomena, gratuitously supplied, put in for convenience, in order to halve, and halve again, the multiplicity of the events that call for recognition? Even if it were possible to overcome, or desirable to ignore, that objection, we should be left with a machine that worked on the pattern following: A is true; B is a part of A; therefore, B is true. Therefore, we must already know the whole truth before we can determine the truth of the part: which is absurd; and we affirm that if the whole has a property, a part of it has the same property: which may be false. Thus reason takes a secondary, and not a primary, place as a means of assay; its use and limits have been illustrated fully in the consideration of the methods of geometry of the first chapter. Granted its postulates, it is able to reveal all the postulates contain and recognize the most remote descendants of the parent stock. But it cannot justify the postulates.

We can accept this disability more easily when we recall that Descartes found only one primary test, and that tentatively—to see very clearly that such and such was a necessary connection—and only one result of its application—*I think, and so I exist.* Nor has anyone found any more. No test has been found that makes the existence of other persons than myself other than a convenient, workable hypothesis, based on the greater symmetry it confers upon the universe, like the heliocentric system of Copernicus.

In the meantime, the stream of science goes on, gathering momentum for its approach to Niagara—if it is going there. We can surely give a better account of it than that. If we have been furnished with no means of recognizing absolute truth, let us examine how far the knowledge which science supplies falls under Lord Balfour's category of the propositions which, though not indubitable; are inevitable—namely, propositions of which it is true that "they cannot be proved, they cannot be ignored, they cannot be rejected, nor are they self-evident." That would give them a position which at any rate is not inferior to that of the proposition that You exist as well as I.

Let us admit that what has passed for science at different epochs has certainly not always led to the truth. The Medicine Man and the Rain Maker represent science to the savage, for they recognize and attempt to control natural powers outside their own. But to us they are charlatans and their knowledge naught. We know a great deal more about rain than they did, and we have no hopes of making it. On a wet day, even in our climate, half a million tons of rain may fall on ten square miles. We have no expectation of organizing phenomena on that scale. Aristotle was a great and accurate observer in Natural History, but his false statement that the nervous system centred on the heart passed muster for many centuries when better things were forgotten. A false doctrine of the movement of the blood was taught and believed until Harvey swept it away. Astronomy got along with the Ptolemaic theory until it found the Copernican. A Euclidean geometry was believed to be necessary until others were shown to be equally possible. There are two models of the atom at present in use—one static and the other circulating. It is evidently little claim to truth that a doctrine passes for science, at any period, and can be called useful science. The fact is so well known that at the present day men of science rarely profess to have any better basis than an hypothesis; *hypotheses non fingo* belongs to a different epoch.* "It is far more important that a scientific theory should be simple than that it should be true," is a statement that may be quoted again.

If, then, the statements of science are unable to claim any absolute truth, and make little effort to rank as inevitable, and as, in fact, they have been rejected, displaced, inverted, and transformed over and over again, it would appear that a simple and sufficient solution of the philosopher's difficulty would be to treat them as mere talk, an example of the instability of statements that have no method. There are, however, two objections. The first is the conviction that all students of external Nature have shared, that their study was leading them into some real knowledge that could not be gained otherwise. They saw something "very clearly and very distinctly," and therefore, I suppose, Descartes would say that some of them were right. It is no answer to say they did not know what it was they saw, or misdescribed it. The second objection is that at the present day these gropings and guessings have led, in the mass, to something which dominates and directs our life. It is too big to ignore. We are bound to treat it seriously and say why it has succeeded.

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* But the hypotheses which Newton refused to "feign" were the attribution of occult qualities to things in order to produce the semblance of an explanation.

Admit that groping and guessing, pursued incessantly and for a purpose, are very searching methods of investigation, yet they are methods which can be applied to any question. Why has science made such signal progress? There are other exercises of the mind which Greek genius started certainly not less hopefully than it did science, which have yet shown no capacity for similar advance. Sculpture and architecture, poetry, philosophy rose in that wonderful dawn to heights certainly not less than those reached by geometry, medicine, and natural history. But in such matters, in spite of the brilliancy of the first achievements, every age and almost every worker has begun again from the starting-point. That is true at least so far as the art does not embody as part of itself a technique and scientific practice of its own. In such cases the technique has followed the history of the science. This is true of painting and music, for instance. But where scientific progress does not enter, we are at the same level as were the Greeks, if not a lower one. Consider, for example, Plato's *Republic*. It is admitted that the basis of the State should be justice, and Socrates seeks to determine what the word means. It means different things to all his interlocutors, as it would to a mixed group of people to-day. A plan is unfolded that has the charm and magic of some great poem, a charm due in part to the feeling that it is a unique, personal expression, a work of art, not a scientific thesis. Nothing is established. If we can imagine the theme treated over again, the author would start again from the beginning, appealing to the same feelings implanted in men's minds, and changing only the clothes in which they were dressed out to those of his own day.

The reason for this is not obscure. The word *justice* is undefined. After the exercise of all the solvents of Socrates' dialectic, it remains undefined; for it is a matter that concerns every man and every woman in the State in their relations with every other. Now, they will rate the things the State can afford them differently. Some will ask adventure and opportunity, some mastery, some the chance to serve, some wealth, some security and peace of mind; they will ask different things at different ages and different stages of their fortune. But we must not dwell too much on these differences, for they are not essential. The poet will seek to allot the multifarious needs and gifts of his ideal State so as to satisfy all. But there is one difference of point of view which no one can reckon with or argue away. Each person, whether he wishes or no, is the centre of his own universe. He sees it from within and cannot get away from it. His view may change because he changes. It may be noble or base, it may be excessive in humility or in pride. It is impossible to say. No judgment can be brought to bear upon it except his own. Hence, anything that concerns the *I* that *thinks* is, and must remain, undefined and primitive. This personality is sometimes grotesquely prominent. Many a person, "educated" too, is incapable of seeing any proposition except to "like" or "dislike" it, or to view it in any other respect than in relation to himself. *De gustibus non est disputandum.* If any discussion is made of such things, as between different persons, it must begin at the beginning every time. Nothing can be carried over as possessing the same necessary value from one *I* to another.

Justice is a noble idea, defined or not, and is seated in every man's mind. Euclid's straight line, on the other hand, is not a noble idea, nor an ignoble idea; it has no human relationships at all, and it is not present in anybody's mind until artificially put there. No straight lines are found in Nature. When perfectly attained it is an abstraction. Yet this arid and unnatural conception may not unfairly be taken as the symbol of all science, a finger-post pointing out the road which has led us to such mountainous wealth. It has proved so invaluable because it was defined. To every user of the idea it meant precisely the same thing. Hence, one worker could start where another left off. Apollonius, Pappus, and Archimedes built upon Euclid's foundations; Pascal, Desargues, and Newton upon theirs, besides hosts of other names, great and small. Geometry possesses in its definitions and deductions a method which is cumulative. Whether its results are valuable or not, it must inevitably grow. Nor does it matter that the postulates of Euclid are not binding. The one thing needful is that workers should understand them in the same way. Nor does any harm beyond waste of time result if a mistake is made. If it is followed out, it will reveal its nature in some contradiction, and can then be discarded.

The apparent difference between geometry and the rest of science is so great that, though it has already been done, it is worth while to point out again how the methods are really at one.

Treat geometry as we treat experimental science. Suppose, for curiosity, we draw a triangle and inscribe a circle in it, and then draw another circle through the middle points of the sides; it might be noticed that the two circles touched one another. That might be an accident of drawing, but after a few trials with different triangles, we might make the guess, or "scientific hypothesis," that it was a necessary fact. Treating it as such, we could derive consequences from it, until at length we came to a deduction that proved it. If the deduction we had drawn was known to be false, it would have disproved our hypothesis. That is exactly the position of the hypotheses that are so freely made in physics and elsewhere. The objection to multitudes of such hypotheses—in fact, hypotheses everywhere and fundamentals nowhere—is that the method is untidy. Its recommendation is that it is easy. These proliferated hypotheses will kill one another out, like the grasses that Nature clothes the earth with. The fittest will survive. There is no hurry. In the meantime, of course, we do not know the "truth," nor even those half-truths that we have agreed to call inevitable. We may in a remote vision see a state when physics, and thereafter perhaps other sciences, will approach the neatness and completeness of Euclid's geometry, where everything has been killed out and cleared away except a few postulates. But even these, we may here recall, are also hypotheses, tentatively held until they are proved or disproved or shown to be superfluous.

We see, however, that science is inevitable in this sense; that it, too, like geometry, has devised a cumulative method, so that, true or false, it must grow with the mere lapse of time. Also, since we desire power and control, it will grow in the direction that gives them, for any other direction will be relatively neglected. In exploiting a discovery after it is made, we may be sure that Hobbs, Nobbs, Stokes, and Noaks will combine, as they combined of old, to "put blue into their line." Now, power and control over the processes of Nature seem to be the same thing as exercising or restraining Nature by the exercise of our own will. We arrive at the necessary rules by the methods of science. The roads by which they were reached give little expectation that one can say why a particular action leads to a particular response; as, for instance, how motion can be stored and become potential by restraint, or how it can be exchanged between bodies. These must be called "Laws of Nature." Still less does it promise to supply a complete, or an adequate, or a representative view of Nature. The control achieved is real, it cannot be denied, but it is external, irrational, and empiric. It has no claim to be more.

None the less, though gained by these imperfect means, the fruits of science have already grown to dominating proportions, and will certainly direct the future course of civilized life. That is inevitable, as the growth of science is inevitable. Now, there are many things that matter more to us than science. The straight line is far less worth dwelling upon than is justice. More important than justice are joy and love, though these are not usually considered germane to a scientific inquiry like the present one. As the methods of science have worked so well in a practical sense, can we not take a leaf out of its book, and turn the same machine to work to make the world more just and joyful and lovely? Why should discussion of these things that matter most go for ever round and round like a pet mouse in its mill, with no progress made, just to pass the time?

The answer has been given already. The cumulative method that is proving so effective in science demands for its operation definitions. These definitions may be very faulty, they may describe things hypothetical and never realized in Nature, such as are the concepts of geometry, they may deal with things impossible to grasp like the mathematician's infinity, they may be provisional like the species of the naturalist, but they must mean the same thing to different users. If we are to advance matters that concern our feelings by the methods of science, we must first define them. It has often been tried. Theories of æsthetics are produced that way, and theories of ethics, but no great lives or works of art, for the reason that great lives and works of art are immediate expressions of personality which cannot be brought into a definition and cannot mean the same thing to different persons.

Science is possible wherever there are definable things. Its process will then go on of itself. We must exclude from the category of definable things all that immediately derive from personality, for there is nothing else in terms of which we can define it. But we can exclude very little else that we can name. The "loosely expressed platitudes" in which Lord Balfour sketched our familiar beliefs are definable things, each isolated and tenable independently of the rest. And consider words themselves. The dictionary is a string of definitions. Words and language are the first attempt to cut experience into a number of definable ideas, and if they are illegitimate and contain a hypothetical treatment of the data of experience, so do every proof and disproof they exhibit. The wise man is reduced to dumb meditation in a solipsistic world.

The trouble arises with a definition when you try to define an object in terms that do not comprehend it.

If we begin with geometry and the conception of fixed figures, the attempt to account for motion leads at once to paradoxes which, like any flaw in an argument, can be made to appear as a contradiction in terms in any place and in any form.

The paradoxes of Zeno will occur to recollection at once. Another and a modern version of the very same problem deserves consideration. The mathematician has provided himself with a discontinuous system of counting by ordinal numbers. He requires to extend its scope so as to comprise change and the continuous, for to deal with changing quantities it is necessary to treat the continuous. But after many attempts, the task of making any binding argument in terms of the continuous alone has been abandoned for lack of an adequate definition. The discontinuous, however, may be defined; for example, the series 1, ½, ⅓, and so on, down to numbers smaller than any you please to assign. Out of these can be built up quantities that are greater than, or less than, and closer to any given continuous quantity by less than any amount you choose to assign. Because they are defined they can be brought into argument and a binding conclusion can be drawn. The continuous quantity is thus securely caught in the meshes of the discontinuous, and is considered as subject to the same conclusion. This artificial procedure, which was not found till after some two centuries of trial of directer methods, is accepted as the simplest valid treatment. It is in effect a bridge from the discontinuous to the continuous, a treatment of the indefinable by means of the defined, and puts beyond question the fact that specific differences are introduced when experience of measured quantity, known as a whole, is cut up into definable parts.

The difficulty that a student of Nature finds on drawing hard and fast lines across his data is not a quibble of the schools. For all the variety of living forms, no one now maintains that the species are distinct. A more searching test is found in the basis of physics. If we ask into what ultimate parts the physicist divides the manifestations he studies, the answer is that he has never been able to make up his mind. He stands on his continuous leg till it is tired, and then he stands on his discontinuous leg, and sometimes he stands on both together. He has oscillated between an atomic theory and a continuum. Both cannot be true. Yet in the most recent phase, where we seemed indeed to be getting to a final basis, both are demanded by the evidence. The quantum phenomena demand an atomic limit, and the interference phenomena demand continuous waves. Hence has been witnessed lately an agony, almost, of theory in the effort to hear the same voice say two different things simultaneously. We cannot give the details of the struggle here, but, on the whole, the peace of the truce seems to favour the continuous view. Yet the truce is at a cost of convention and abstraction that it is difficult to regard as a serious description of Nature. Philolaus, long ago, in framing a theory of astronomy, invented an *Antichthon,* a Counter-Earth, which no one had seen or ever could see, in order to bring up the number of bodies to what he imagined a symmetrical theory required. This is no greater strain upon our powers of belief than the completions of fact required by the Wave Dynamics, nor do they appear to me one whit more credible than the conjecture of the solipsist, that no external world exists at all.

It is therefore necessary to examine very closely the way in which definitions in general came into being. Experience is given as a whole. It does not even permit us to separate certainly the existence of other persons from ourselves. It is given as a very vague whole, moulded into shape in our earliest infancy when we can neither talk nor be talked to. We endeavour to make it manageable for the purposes of control by cutting it into parts. Whatever natural distinctions appear we make absolute. Where there is a quality we accentuate it. We select. We select things soft for pillows and hard for knives. We cut the rough mountain-side into squared stones for our houses. We pulp the amorphous inside of a tree and spread it into thin sheets of paper and then print black on white upon them for words. All the same, the dissection, as we know, is very imperfect. There is nothing to show that the whole of the scheme of space construction which we use and suppose other persons to use, including the distinction of space and time, is not arbitrary, and of no more validity than the colours which some associate with the days of the week, or the patterns they associate with numeration. It is often self-contradictory, as when we treat a fluid as continuous, though made up of atoms. At best we can call it tentative and provisional. But, as we have seen, none of these objections forbid the use of the dissection scheme for the purposes of science, provided we can know, or even guess, that the dissections made by different persons are the same as our own.

The use of words and names produces no increase of power and no reliable machinery for communication in those regions which are most direct expressions of personality, because personality is indivisible. But the stamp of personality is not equally impressed upon all our knowledge. The stamp of personality is what is styled the " personal value " attached to any external experience. Suppose a number of external experiences are presented to different persons; each would attach his own system of values to them, and for him this system would be inseparable from the experiences themselves. His system of values may or may not be the same as that attached by another person. It may vary under change of his own circumstances, or whether he is young or old, or has much or little to gain by an event. All this is unessential whether it results in identity or difference. There is, however, an essential difference, and that is a difference in origin.

Now let us make the supposition—which is inevitable if we are to proceed at all, that a number of persons are exposed to the same experiences, and mark these experiences each with their own set of values. How can we make science from this, since science requires agreement in abstraction? Evidently science will be formed of those parts where the personal impress is negligible. In its purest forms it is confined to experience infinitely remote from personal impress.

Again to employ the language of mathematics, the personal system of values is an "essential singularity" in estimation. An essential singularity cannot be removed, but if it is projected to a sufficiently remote distance, it does not interfere with calculation, and is as good as absent. Different parts of experience grade insensibly from mathematical and physical experiences which are entirely abstract from life and infinitely remote from the personal factor, through all intermediate stages, until we come to those regions where personality rules. Naturally, to a person, the last is the region that matters most. But the first, the abstract one, is the region that permits the full operation of the cumulative scientific method.

Before leaving this subject it is worth while to turn a glance upon the middle region, which shares, imperfectly, the characters of the two extremes. Whether it is recognized as science of a type or not, the possibilities open to the united effort of many persons are so obvious that they are tried again and again, even when the necessary conditions are very imperfectly fulfilled. The most prominent practical instance is found in societies bound together in a political system. Rousseau imagined a primitive Contract as underlying society. The essence of a contract is the voluntary restriction of personal liberty on all sides. All societies require this, and in return they give defined advantages. In large groups, as in small, informally and tacitly or in written shape, we see the effort made to introduce order, definition—science, in fact—with a view to gaining the advantages that follow when many act as one. Corporate interests, patriotism, personification of the State, any form of *esprit de corps,* the " cash nexus " of trusts, the abnegation of personal responsibility by soldiers, will be illustrations that occur at once of loosely defined conventions that are widely accepted. It will be noticed as a common characteristic of these that any debate about the convention itself is taboo, lest unrestrained thinking should prove a solvent of it. It is assumed that the convention is endowed with an authority that transcends thinking. The essential tragedies of the world arise when one such convention comes in conflict with another. The mere sceptic, faced by some insistent convention, can usually employ his unrestrained thinking to think of some reason why he should give way to it. It would take us too far to amplify a theme which extends over all civilized life and bristles with disputed questions. Sufficient is it to note that the conventions succeed, as might be expected, more or less imperfectly, and are in a state of permanent instability and flux. For on the scientific side the matters treated are not liable to full definition, and on the personal one the machine may operate to crush the interests of the individuals who have united for the purpose of making it.

# CHAPTER V

## *SUMMARY, PRESENT AND FUTURE*

I WOULD collect in the present chapter a restatement of the views to which our argument has led.

Science increases, be it true or false, and its increase results solely from its possession of a cumulative method. The secret of this method is definition, which is expressed in the use of words themselves and probably preceded them. The separation appears to be made in consequence of the limitation of the conscious intellect. Without definition in some degree, the conscious intellect is helpless The intellect appears to be able to deal only with one thing at a time, perhaps because of the one-dimensional time sequence imposed upon it Be that as it may, one thing at a time means the dissection of experience into units, followed by the introduction of " causation " or some other convention, to unite it again. Now is that valid?

Let us remark that whether it is valid or not, it is not the method of philosophy, which demands that we should attempt to grasp the whole, even at the cost of some vagueness. Let us also remark that the method of dissecting experience contains a postulate, an assumption, and can only be valid in the region where this postulate is true, or, in other words, the region which that postulate defines. For experience is given as a whole, and need not be separated into

*I* and *Other*, if we do not choose to do so. To suppose the separation made, and other separations subsequently, is the postulate; it is a special treatment of experience, and can never be proved to correspond with Nature, and what is of more practical importance, it cannot be proved that it does not exclude aspects of Nature that ought to be retained.

Science makes no pretension to hold a talisman that will tell the true from the false. It proceeds by trial and error. Yet its proceedings are not random, for they are guided by workers who desire knowledge or power, or both. Among the things they say are some, and a great number, that hit some mark and call up a response in Nature. These ones, then, assume a permanent importance, and naturally are made a base for further advance. Science has no means of telling the connection between its word and Nature's response. The fact must be stated simply as a datum, and called a Law of Nature.

In the matter of dissecting experience into units, the first separation made is the existence of persons other than oneself. Like other separations, the truth of the step cannot be proved from experience or in any other way. Its justification rests on the same ground as the step in astromony which deposes the earth from the centre and assigns to it a place as one of the planets. It cannot be proved to be "true," but from some points of view it introduces an enormous improvement in the symmetry of the scheme. As regards the belief in the separate existence of other persons, the intellect could not get to work without it. In that sense, it is "inevitable," yet we must recognize that it is only for the purposes of the operation of the intellect that persons must be regarded as distinct. Otherwise they may be thought of as merging into one another and into the whole, insensibly.

How many difficulties are introduced by the view that persons are distinct from one another, it is almost superfluous to relate. Roughly speaking, they are the whole of the difficulties of philosophy. After we have distinguished them from one another, the first thing we must do is to bring them together again and explain how they can communicate with one another.

Now our datum is experience given as a whole, which we see as continuous. To the continuous there is neither beginning nor end, and every part implies every other part. Discontinuous elements imply nothing, each gives itself and no more. We can arrange them in serial order, and draw consequences accordingly, but it is an arbitrary step. Before we can make the discontinuous elements into a chain, we must unite them with a link of "causation" or merge them in a medium of "transcendental reason" Strictly, the logical position is the same as when Hume left it.

If then science connects "good pasture" with "fat sheep," or as it usually does, two things less familiar, and calls the connection a "Law of Nature," we see that science first separates the two objects, and then passes a law to bring them together. It is only from the confusion arising out of the great multiplicity of the operations that the character of the step is not seen.

Science has never been an unimportant matter, for it is nothing else but all the gatherings made by the intellect. But the process went on for a long time so slowly and gently, at so many separate points, that its course was insensible. While this was so, the summary verdict of the last paragraph might seem adequate. For it was not clear, as it is clear to-day, that the operations of the intellect were destined to extend man's power, inevitably and overwhelmingly.

We have then to say why a null process like splitting an idea into two parts, and subsequently reuniting the parts, can lead to increase of power; and subsequently to say what kind of power it is and what limits there are to its fruits.

It is pretty clear how uniting separated parts can lead to increase of power. The union can be made by an act of will. It is like switching on an electric light. You find the switch in the dark, you turn it on, and there is light where there was none before. The constructive operation of the intellect in science consists in finding and marking the switches. Much more obscure is it to say why there are live wires behind the switches. To find the switch and to name it, and to turn it on, are very different things from understanding electricity. That is the real question, but, frankly, we are out of our depth here. It seems to imply an earlier separation, but that is only if we insist on regarding the whole system as null. One might conjecture that it is not null. There seems little prospect of comprehending the matter. In any case, a separation, if one was made, is anterior to the operation of our own intellect or that of anybody else. The distinctions we employ are formed in their main lines in earliest infancy. They are gradually amplified. Though they serve us very well, they are probably no more an essential to life than is a backbone. They can be nothing but an attempt to mark for recognition, and in a way not patently self contradictory, some differences that are real, whether definable or not. That they stand us in good stead, as guides for the exercise of will, is apparent from the results. The added power is beyond question. It is indubitable, too, that the power will increase when we have discriminated by trial other points so that we may direct the will more exactly. That is, the service, the intellect, and science, which is its book, has done and is doing for the will. Without it, however, the will is far from being helpless. Persons can influence other persons, whole to whole, if the will is directed aright, without any science, with a speed and range and completeness that science cannot copy.

Clearer as well as less abstract is the question of the kind of power that we can expect from science, and the limits of it. Science is knowledge into which no personal element enters. This is a necessary condition if it is to mean the same thing to different persons and so gain the advantage of the cumulative method. Now all observations, being made by persons, contain a personal element initially. Science is the outcome when the observations of two persons are compared, or of a number of persons, or by "induction," of all persons, and the personal element eliminated. Or if we do not like the mathematical idea of elimination, we may say that science is knowledge when the observer is infinitely remote. Just in proportion as this condition is fulfilled, so science has progressed. Because the subject-matter of astronomy was remote from the observer and could readily be made perfectly remote by describing it in geometrical abstractions, so astronomy grew to maturity before any other science. The limits, and the only limits of science, came from this condition of remoteness from the person.

This, however, is a heavy limitation, and we see that science can never be more than partial knowledge. We are familiar with the fact that as a practical guide, theory is always dangerously incomplete. Its method is first to remove the life from any phenomenon before discussing it. Out of Nature's bounty of wild flowers it collects laboriously for its own reference a sort of *hortus siccus*. But the personal relationships must always be the ones that matter most to us.

Yet this has been found worth remark. Whether we like it or not, the progress of science will not be gainsaid. It is automatic as well as cumulative, for the instincts of curiosity and the desire for power ensure it. Hence the influence of science upon life, one-sided though it be, will grow. The whole of civilization is its achievement. It has become so much to us that we cannot and do not wish to imagine ourselves without it. Like other possessions, it possesses us. And it will close more strictly around us. We have started by building a shelter against Nature's rough weather and have gone on improving it till now we can hardly get outside it, and all our conscious and united effort goes to closing it in still further.

Yet we are not entirely without resource. What the intellect itself has contrived does not transcend the intellect. It cannot turn back from its course the river of power which flows in a channel the intellect has made definite. It did not create the power and knows nothing of its nature. But the intellect can comprehend its own work. The so-called knowledge which it has pieced together one way it can piece together in another way and so prove its nullity. Although, as I esteem it, the intellect is a frame so limited and of such a peculiar shape that it is impossible to put any real picture of Nature within it, however reduced, yet there is no limit to the function of the intellect in explaining and recognizing the mark which it has put upon reality, including even the conventions of space and time. We may reject all that bears that mark as probably fallacious.

This is the outcome of our quest We have learned how to distinguish the true from the false, by showing that the shapes the false assumes are not inevitable; but we cannot give a name to the true when we have found it. The methods of definition and discrimination, thinking and speaking in sequence, are the only methods we can practise. They lead us to the truth, but with a chasm between, their own side of which they are adequate for exploring. They cannot cross the chasm, because, in reality, the chasm does not exist. We have dreamed it, and if we wake up and shake

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ourselves loose, the details of our dream, the resources, methods, and result of the intellect, cease to be.

The One remains, the many change and pass;
Heaven's light forever shines, Earth's shadows fly;
Life, like a dome of many coloured glass
Stains the white radiance of Eternity,
Until Death tramples it to fragments——

But we are now in a region where every statement becomes paradoxical and words are perilously near to nonsense. I prefer to leave the matter here, for I can add nothing to what has been often and better said already.

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